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**Article**

## EU policy objectives and energy investment decisions

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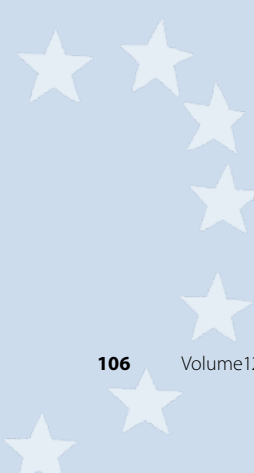
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## ABSTRACT

*EU energy policies have changed focus in the last few years with a view to substantially reducing energy import dependency and greenhouse gas emissions. The EU Commission has played a leading role in defining the new orientations. The implementation of the EU policy objectives approved by the Council of March 2007 will require a substantial expansion of energy investments. However, the degree of uncertainty affecting investment decisions remains high, notably in relation to the pricing of CO<sub>2</sub> and high energy-price volatility. To make the necessary investment in low-carbon technologies happen, energy policies need to establish a credible long-term framework that reduces uncertainties.*

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# EU policy objectives and energy investment decisions

## 1. Introduction

This paper analyses the implications of the EU policy objectives on energy investment decisions from an investor's angle. Investors are confronted with changing policy objectives, unclear definition of the objectives, and debates among policy makers on the importance of different objectives and the ways to achieve them. This introduces substantial uncertainties in a context where the achievement of policy objectives, like those related to security of supply and climate change, has substantial implications for investment decisions.

Government policies play a role in all economic activities. In the energy sector this role is very significant. Energy is traditionally considered a fundamental service because economic activity is significantly affected if energy services are not of good quality – in terms of both availability and affordability. Therefore, governments have traditionally intervened in energy matters. In liberalised markets, government policies influence investment decisions in different ways. The regulatory framework, the general policy objectives, and investors' perception of the soundness and stability of policies are key considerations in energy investment decisions. Outside the energy sector, government energy policies also play a significant role, particularly with the aim of improving energy efficiency or favouring or penalising the use of certain energy sources.

Section 2 presents the developments of the EU energy policy and the most recent EU energy objectives. The latest IEA World Energy Outlook (IEA 2006) confirms that the 'reference' world energy scenario is environmentally unsustainable, as energy related CO<sub>2</sub> emissions will increase substantially in coming years (by 55 percent in 2030 compared to 2004). This implies that it is necessary to curb CO<sub>2</sub> emissions at world level. The need to substantially decrease greenhouse gas (GHG) emissions and oil and gas dependency of the EU has triggered a revision of the energy policies in the EU. The recent energy policy for Europe, which was adopted by the European Council of March 2007, defines ambitious energy objectives at EU level. Achieving these objectives will require more government intervention and a coordinated approach at EU level.

Section 3 analyses the energy investment outlook in the EU, taking into account future energy demand growth and the need to replace or renovate facilities reaching the end of their lifespan. The objectives adopted by the European Council of March 2007 have substantial implications for energy investments. The energy efficiency objectives will significantly reduce the needs of investment in the energy sector, but will imply significant investments in the energy-consuming sectors. The objectives concerning renewable energy will imply a substantial increase of investment in renewable energy and less investment in imports and use of fossil fuels.

In the final section of the paper, the different factors that influence the investment decision are analysed. The key factors that influence the profitability of energy investments are policy and regulation, as well as energy prices. The current context is very challenging for energy investors because of significant uncertainties related to the revision of energy policies in Europe and increased volatility of the energy markets. Most of the issues raised for the energy sector are relevant to energy-intensive industries too, such as metallurgical industries, petrochemical or cement factories.



*Juan Alario*

## 2. The energy policy objectives of the EU

### 2.1 The changing focus of EU energy policy objectives

A feature of the development of the energy policy in EU countries and in other countries is that the importance of the three main objectives (that is, security of supply, limiting environmental impacts, and competitiveness) has varied over time (Finon 1994).

***The oil crisis in 1973 led to a substantial reinforcement of public intervention in energy matters.***

After the first oil crisis of 1973, security of supply was the main objective. The emphasis was on reducing energy import dependency, in particular on oil imports. The oil crisis led to a substantial reinforcement of public intervention in energy matters. Governments led the response to the crisis, as they, directly or indirectly, controlled the energy sector. Therefore, the response to the crisis was essentially national. The European Commission developed a role of 'benchmarking' and 'peer review' process of national energy policies at European level by establishing common energy objectives.<sup>1</sup> However, these objectives reflected the sum of the national objectives rather than common EU objectives.

The results of the policies were spectacular. In just over ten years, the level of energy dependency of the EU-12 decreased substantially, from 65 percent in 1973 to around 45 percent in 1986; oil import dependency fell from 62 percent to 33 percent in 1986. This was achieved largely by reducing the use of oil in power generation, which declined from 42 percent to 16 percent in the same period. In addition, the energy intensity of the economy decreased by some 22 percent in 1973-86. While the changes were impressive, their costs were high in many countries. The cost of the nuclear programmes in some countries turned out to be very high, such as in Spain and in the United Kingdom.<sup>2</sup> Substantial over-capacities were created in the electricity and refining sectors as a result of optimistic assumptions about energy demand growth, which took many years to absorb.

The oil price collapse of 1985 led to a change of priorities of energy policies in Europe and to less public intervention. The policy objective of lowering energy supply costs ('competitiveness') became the most important one. The main instrument used was the gradual introduction of competition in the energy sector. The control of the sector by governments decreased and a process of deregulation was initiated in the electricity and gas sectors.

Since the end of the 1980s, a number of EU countries developed policies aiming at introducing competition in the electricity and gas markets, a process pioneered by the United Kingdom. This trend reflected a similar one elsewhere in the world. The Commission supported the liberalisation of national energy markets with a view to creating an internal EU energy market. Creating this market became the long-term objective intended to give new impetus to an EU energy policy. After a long process of negotiation, both Directives aiming at a gradual opening of the electricity market (Directive 96/92/EC) and the gas market (Directive 98/30/EC) were approved in December 1996 (electricity) and June 1998 (gas). Differences across countries in regulatory frameworks, 'national styles' and the dominance of incumbents have dramatically influenced both the development of the newly liberalised energy markets and the business strategies of energy companies (Finon and Midttun 2004). Because of this and the limited interconnection capacity between EU member states,

1 The Treaty of Rome does not include specific provisions for the energy sector, although coal and nuclear are at the origin of the process of European integration. The different attempts to create a common energy policy have not achieved substantial results up until now. However, common energy strategies have been developed in certain areas, using the Treaty provisions.

2 For instance, the last two nuclear power stations commissioned in Spain attained cost levels higher than €3,500/kW (Alario 2001).

significant barriers to enter national electricity and gas markets continue to exist in most member states. This is well documented in the annual reports of the Commission on the implementation of the gas and electricity internal markets (European Commission 2005).

Since the early 1980s, another trend has been at work: policies to reduce the negative environmental impacts of energy activities. The energy sector is the main contributor to air pollution. Initially, policy measures focussed on reducing the 'traditional' sources of air pollution such as emissions of SO<sub>2</sub>, NO<sub>x</sub>, and dust. This was reflected in the introduction of tighter emission standards for new installations, a gradual reduction of emissions from existing installations, and the development and use of less polluting forms of energy, notably natural gas and renewable energy. Later, fighting climate change gradually became an important energy policy objective due to the increasing scientific evidence that human activity, particularly energy production and consumption, leads to an increase in the concentration of GHG and, thus, global warming. The importance attached to climate change has increased in the last few years together with policy makers' acceptance that it is necessary to substantially reducing GHG emissions (in the past the objective was just stabilising or slightly decreasing GHG emissions).

Towards the mid-1980s, the decline in EU energy dependency discussed above came to an end and dependency started to slowly increase again, reviving the debate on security of supply. A key milestone of this debate was the Commission's Green Paper on security of energy supply (European Commission 2000). However, few concrete policy measures followed from this, largely because energy markets functioned smoothly and oil prices were relatively low. Since 2003, the energy security debate has gained new momentum due to rapidly increasing oil prices and efforts by the main energy-exporting countries to strengthen state control over energy resources and to restrict the entry of foreign energy companies.

Several EU countries, such as the United Kingdom, have started reviewing their energy policies with the aim of reinforcing their climate change and security of supply objectives. The European Commission has been very proactive by launching a debate at the EU level on energy policy. The clear need for a coordinated EU approach to address climate change and security of supply issues gives the EU institutions an unprecedented opportunity to develop a common energy policy.

Indeed, in recent years, there has been an intensive debate on the goals and instruments of energy policy – a debate that will continue in the future. But what seems to become clear already is that the period of limited government intervention in energy matters, which started in the mid-1980s, is coming to an end. This is because the objectives of significantly reducing GHG emissions and improving security of supply requires much more government intervention in energy matters. Indeed, some have observed that the conditions of the energy market have changed so fundamentally around the year 2000 to give rise to a new energy paradigm (Helm 2005). Around the turn of the century, a set of events began to take place in the energy markets that put the conventional wisdom of the 1980s and 1990s under considerable stress. "These events combined with 'new' concerns, notably the issues of security of supply and of climate change. ...this shift in external circumstances, combined with new knowledge about climate change, cannot be adequately addressed within the existing paradigm of privatization, liberalization and competition. Though these policies continue to contribute both to the context and the outcomes, they are no longer sufficient" (Helm 2005, p 2).

In a way, EU energy policies have come back to the situation of the first and second oil crises. However, in contrast to the previous period, EU countries' energy sectors are now open to competition and not directly controlled by governments. Therefore, there will be new forms of intervention (market and non-market instruments) to achieve key policy objectives.

***Recent years have again seen an intensive debate on the goals and instruments of energy policy.***

***EU institutions should play a leading role in defining energy policies to ensure the achievement of the key objectives in the most effective way.***

The EU Commission policy is defined in the Green paper “Energy” published in 2006; followed by the so-called “Energy package” of January 2007, which includes among others, the communication of the EU Commission “An Energy Policy for Europe”. The latter presents the key energy objectives of the EU proposed by the Commission. After some hesitations, the Council adopted the key objectives proposed by the Commission at the European Council of March 2007. Through these different initiatives (presented in the different papers included in the “Energy Package”), the Commission has been able to play a leading role in the definition of EU energy policies. The key issues at stake clearly justify that the EU institutions play such a role to ensure the achievement of the key objectives in the most effective way.

The climate change objectives are presented in a clear and quantitative way in the Commission’s communication. The Commission proposed to commit now to achieve at least a 20 percent reduction of GHG emissions by 2020 compared to 1990, regardless of the decisions at the international level. This objective has been adopted at the European Council of March 2007. The Commission sees this as a concrete contribution to the objective in international negotiations of achieving a 30 percent reduction in GHG emissions by developed countries by the same date. This means that EU countries would commit to 30 percent reduction if developed countries adopt this objective. In addition, to limit adverse effects of climate change, global GHG emissions have to be reduced by up to 50 percent compared with 1990 by 2050, implying reductions in industrialised countries of 60-80 percent by the same year.

Regarding security of energy supply, the focus is on limiting the security threats related to the increasing dependence on imported oil and gas. The objectives in this area are multidimensional. The two key objectives are to reduce the dependence on imported oil and gas and to further diversify imports. On the latter, it is explicitly stated that “it remains important for the EU to promote diversity with regard to source, suppliers, transport routes and transport methods” (European Commission 2007a). The growing dependence on imported oil and gas carries political and economic risk, which the policy aims to mitigate. The Commission does not give quantitative targets on security of supply, as it does for climate change objectives.

Finally, in the Commission’s communication, the competitiveness objective has different aspects. Obviously, the aim is to achieve lower energy costs, but other objectives are also pursued, such as reducing the exposure to “the effects of price volatility and price rises on international energy markets, as well as dealing with the consequences of the progressive concentration of hydrocarbons reserves in few hands”(Commission 2007a). This is related to the objective of import diversification under the security of supply objective. Another related objective is to contribute to growth and jobs in Europe by leading the rapidly growing market for low-carbon energy technologies, notably renewable energies.

The objectives related to increasing energy efficiency or renewable energy sources are discussed in the next sub-section. This is because these objectives are considered instruments or means to achieve the policy objectives.

## **2.2 The EU energy mix and its role in achieving energy objectives**

The recent papers on the EU energy policy do not analyse clearly enough the energy mix coherent with the objectives proposed. This is not surprising because the energy mix to achieve the objectives is less clear than it appeared in the previous crisis.

With the oil price collapse of 1985, gas became a low-cost and environmentally competitive option to cover energy demand, particularly for electricity production. Gas resources were considered abundant and from relatively diversified origins. The gas competitiveness was based on the general perception that oil and gas prices will remain relatively low in the long run. For all these advantages and in a context of a liberalised energy market, gas became the fastest growing energy source (only surpassed by renewable energy) in the EU and in many other parts of the world.

However, the view on gas has changed since early 2000. For one thing, the substantial rise of oil prices since end-2003 has dramatically reduced the competitiveness of gas in power generation. At present, without taking into account a price for CO<sub>2</sub> emissions, electricity from a coal-fired power station is cheaper than electricity produced in a combined-cycle gas turbine power station (CCGT) using gas (see Section 4). This explains that at a world level, coal consumption is now increasing faster than gas, particularly in Asia. For another, for the EU, gas now raises substantial security of supply concerns, contrary to the previous situation. This is related to the growing EU dependence on imported gas.

These factors should normally lead to the expansion of coal for power generation in Europe. However, this is happening to a very limited extent at present due to the climate change policies. Latest EU forecasts (European Commission 2006c) suggest that in a business-as-usual scenario, gas demand in the EU is expected to continue to grow relatively fast up to around 2010, stabilise thereafter, and decline by 2030. An eventual increase of coal consumption would increase CO<sub>2</sub> emissions, unless it is combined with carbon capture and storage (CCS), and would thus contradict climate change objectives. This explains why there is no agreement at the EU level on the role of gas and coal in the energy mix. Some EU countries are in favour of a revitalising coal, particularly those with a long tradition in coal mining, such as Poland and other new member states.

At present, nuclear covers about 15 percent of total energy consumption and over 30 percent of electricity production of the EU. In principle, nuclear power is a good option to achieve key EU energy policy objectives. In practice, nuclear power faces public opposition in many countries, reflecting concerns about nuclear safety, notably related to nuclear waste and decommissioning. Again, there is no consensus at the EU level on the future role of nuclear; with some countries fiercely against and others in favour.

In this context, energy efficiency and renewable energy are the two key options to achieve the objectives of security of supply and climate change, where there is agreement at the EU level. Reflecting this, the European Council of March 2007 endorsed a binding target of 20 percent of renewable energies in overall EU energy consumption. In light of these new EU energy targets, national energy plans are to be prepared for endorsement at the EU level, reflecting the burden sharing that still needs to be agreed on by member states. Furthermore, the European Council stressed the need to increase energy efficiency in the EU, so as to achieve the objective of saving 20 percent of energy consumption compared to projections for 2020.

In principle, the achievement of these objectives should result in a reduction of 20 percent of CO<sub>2</sub> emissions from the energy sector, everything being equal. However, achieving these objectives will not be easy. In the baseline energy price scenario of the Commission (European Commission 2006c), the renewable energy target should lead to a significant increase in the cost of energy (see Section 3).<sup>3</sup> The case for public policies to support the expansion of renewable energies largely rest on the notion that financial support to R&D activities and to the deployment of these technologies

***Increasing energy efficiency and the share of renewables in Europe's energy mix are the two key options to achieve security of supply and climate change objectives.***

<sup>3</sup> In this scenario, the price of oil rises from \$45/bbl in 2010 to \$58/bbl in 2030.

in the early market penetration phase will lower the costs of such technologies in the medium to long term. Effectively, market expansion of some of these technologies, such as wind, has resulted in significant cost declines through scale and learning effects – a topic covered in greater detail by Kolev and Riess (this volume). However, future cost developments, as for any new technology, are very difficult to forecast. Concerning the energy efficiency target, in principle it can be achieved without raising the cost of energy under the current energy price scenario. However, as Schleich (this volume) and Sorrell *et al.* (2004) argue, there are substantial barriers to boosting energy efficiency (imperfect information on energy efficiency possibilities, hidden costs, split incentives, and others). Some of these barriers require a policy intervention, whereas others do not.

Therefore, it seems necessary to have more options to achieve the EU objectives to limit the risk of relying practically exclusively on energy efficiency and renewable energy. The Commission proposal to develop carbon capture and storage (CCS) appears as a relatively uncontroversial alternative to renewable energy sources, particularly in a transitional period until low-carbon technologies are fully developed. CCS allows using fossil fuels for electricity production without producing substantial amounts of CO<sub>2</sub> and it can contribute to opening a potentially economically viable route to the mass production of hydrogen (coal gasification or gas reforming). However, CCS technologies are only expected to be commercially available by 2020 and the cost of CO<sub>2</sub> abatement with CCS is high at present, but R&D activities might – as it is the case for renewable energy and energy efficiency – considerably reduce their costs in the medium term. The Commission proposes (European Commission 2006a) to support the construction and operation of up to 12 demonstration power generation plants including CCS by 2015 and to provide a clear perspective of when coal-and gas-fired plants will need to install CO<sub>2</sub> capture and storage. On the basis of the existing information, the Commission believes that by 2020 all new coal-fired plants should be fitted with CO<sub>2</sub> capture and storage and existing plants should then progressively follow the same approach.

### 3. Energy investment outlook

**The information available on the historical development of EU energy investments is very limited.**

The information available on the historical development of EU energy investments is very limited. During the period 1970-86, EU-7 energy investments followed a cyclical pattern (Alario 1988).<sup>4</sup> More specifically, investments increased by over 40 percent after 1973, and by an additional 20 percent after the second oil crisis. A considerable part of this investment occurred in the electricity sector, mainly as a result of the construction of new power stations – overwhelmingly nuclear – to replace oil-fired electricity generation. Investment in oil and gas production, notably in the North Sea, was another important contribution to the investment boom in this period. At the same time, investments in refineries decreased substantially. Since the mid-1980s, energy investment declined and since the mid-1990s investments remained relatively constant in real terms (see Table 1). The energy investment trend since the mid-1980s is explained by the substantial overcapacities in the power sector, which – in turn – are due to the earlier investment boom and gradually declining growth of energy demand. Given these overcapacities, there has been a limited need for additional energy investments in the last 20 years.

For 2006, the level of gross fixed capital formation (GFCF) in the energy sectors of the EU-25 can be estimated at €80 billion per year (own estimate based on the information presented in Table 1). But the information available is unreliable.<sup>5</sup> This figure is equivalent to 6 percent of overall GFCF.

<sup>4</sup> The seven countries are: Germany, France, Italy, the Netherlands, Belgium, the United Kingdom and Denmark.

<sup>5</sup> In the Eurostat statistics, the countries that report energy sector investment account for 72 percent of EU-25 GDP and 70 percent of gross fixed capital formation.



The electricity and gas sectors have accounted for most of the investment (around 80 percent) in recent years, followed by oil, gas and coal production (10 percent) and oil refining and distribution. Investment in renewable energy has rapidly increased in recent years and now accounts most likely for €15 billion, which is about 20 percent of the total energy sector investment.<sup>6</sup> Energy efficiency investments are difficult to estimate and are not presented in the statistics.

**Table 1. EU-25 gross fixed capital formation in the energy sector, 1995-2004**

	1995	2000	2001	2002	2003	2004
Billions of euros (1995 prices and exchange rates) unless otherwise indicated						
<b>Energy sub-sector</b>						
Electricity, gas, and water supply	63.0	56.6	57.7	59.5	61.2	61.0
Mining and quarrying of energy producing materials	10.8	6.4	7.9	8.9	8.2	7.0
Manufacture of coke, refined petroleum products and nuclear fuel	6.2	5.5	4.8	4.5	5.3	5.2
<b>Total</b>	<b>80.0</b>	<b>68.5</b>	<b>70.4</b>	<b>72.9</b>	<b>74.7</b>	<b>73.2</b>
<b>Memorandum items</b>						
In % of GDP	1.6	1.2	1.2	1.2	1.2	1.2
In % of GFCF	8.0	5.5	5.7	6.0	6.1	5.9

Source: Eurostat and own calculations

Notes: Mining and quarrying includes extraction of crude oil and natural gas.

Investment needs in the energy sector depend on demand growth and the replacement of existing capital stock reaching the end of its economic life. Total energy demand growth will continue to decrease in the medium to long term. In the baseline scenario, the Commission forecasts total energy consumption to be 15 percent higher in 2030 than in 2000 (European Commission 2006c). The fastest expanding energy sources are forecasted to be renewable energies (+242 percent in 2030 compared to 2000), electricity (+51 percent) and gas (+38 percent). These three energy sources will concentrate most of the investments in coming years. The rest of the energy sources are expected to decline or remain constant (nuclear -11 percent; coal -4 percent; oil +1 percent).

As gas import dependency is expected to increase from over 50 percent to 84 percent in 2030 in the baseline scenario, gas imports are expected to expand by 72 percent in the period to 2030. This implies that the capacity of gas import infrastructures will need to be expanded to enable additional gas imports. In addition, new gas import capacity may be needed to diversify import routes and methods of gas imports, notably in favour of LNG import terminals as they offer more flexibility than pipelines.

However, this baseline scenario is environmentally unsustainable (CO<sub>2</sub> emissions increase) and the dependence on imported oil and gas will increase substantially. Therefore, as indicated before, the EU energy policy aims at changing this scenario to reduce CO<sub>2</sub> emissions and import dependency. This will significantly influence the investment needs. Renewable expansion is targeted to be faster

***Investment needs in the energy sector depend on demand growth and the replacement of the capital stock that reaches the end of its economic life.***

<sup>6</sup> Own estimate.

than in the baseline scenario (the objective is 20 percent of total energy consumption in 2020 while the forecast is 10.4 percent in the baseline scenario) and energy efficiency policies are envisaged to reduce energy demand growth. If successful, the energy efficiency objective (-20 percent by 2020) would imply that by 2020 the EU primary consumption would be slightly lower than today (European Commission 2006e).

***If EU energy efficiency objectives are achieved, electricity demand growth will be significantly lower than foreseen so far.***

If the objectives of the Commission are achieved, electricity demand growth will be significantly lower than in the baseline (0.6 percent per year in 2000-20). Similarly, gas consumption will expand at a rate of 0.5 percent per year in the same period, which will result in a lower gas import dependency than in the baseline scenario. The main impact of these objectives will be in the power sector with a pronounced rise in renewable electricity and a fall in fossil fuel-based electricity (Commission 2006d). More specifically, the use of coal and lignite in power generation is envisaged to drop by 50 percent by 2020 and to further decline thereafter. Gas expansion in the power sector is foreseen to be much slower than in the baseline scenario (+20 percent increase in 2020 compared to 2000). In part, this increase is related to the expansion of combined heat and power (CHP) plants, where gas is the preferred fuel. In line with these trends, the electricity capacity using fossil fuels is forecasted to halve by 2020. However, the Commission's scenario foresees an increase in biomass-fired power generation capacity equivalent to the decrease of the capacity using coal or lignite. It should be noted that, with some adaptations, biomass can be used in combination with coal or lignite in existing or new coal-fired power stations.

A significant part of the existing capital stock in the energy sector will need to be decommissioned in the next 20 years. Most of this will be in the power sector and very little in the gas sector, where the infrastructure is relatively modern in most EU countries.

A substantial share of the existing electricity capacity came on stream in 1980-85. Therefore, decommissioning of this capacity will reach a peak in 2020-25, based on an average lifespan of 40 years (see Figure 1). Concerning electricity grids, replacement needs to pick up by 2020-30 for high voltage grids (CESI 2005) and renovation of existing medium-low voltage grids will also be significant in the period to 2030. Electricity companies have substantial flexibility as to the decommissioning of existing power stations. They can accelerate or delay these investments depending on market circumstances. In the current context, characterised by substantial uncertainties, they have tended to delay decommissioning of existing power stations. This became quite apparent in the approach they adopted in order to meet the stricter pollution emission limits imposed by the Large Combustion Plan Directive. Most companies have opted to install additional anti-pollution equipment in existing power stations, rather than decommissioning them and building new, more efficient ones. This concerns mainly existing coal power stations, as those using gas and oil are practically not affected by this regulation.<sup>7</sup>

Moreover, investments in the electricity grid have been relatively low in the past, for different reasons. This is highlighted by the European Commission (2006b), which indicates that progress in the development of energy networks, notably electricity grids, has been insufficient.

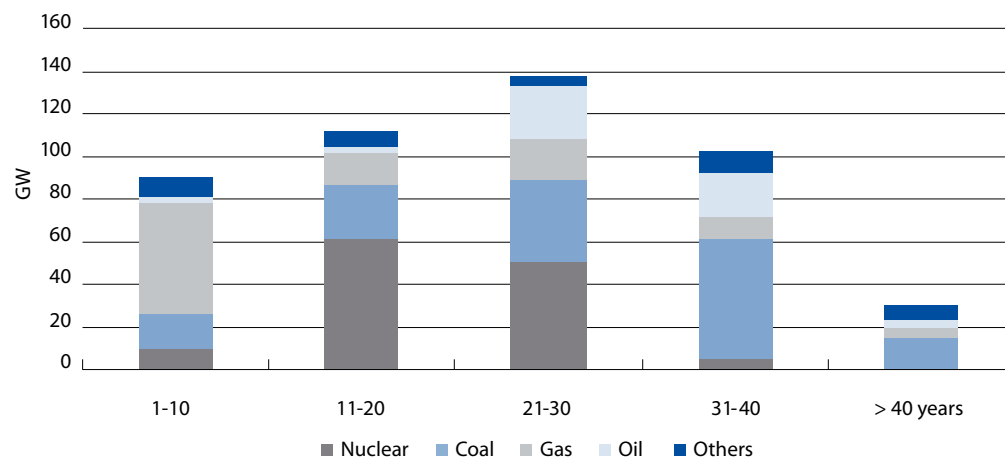
In its baseline scenario, the European Commission (2007c) has projected the cumulative energy investment needs for the period 2005-30. As Table 2 shows, they are estimated at €1,790 billion,

<sup>7</sup> Power stations using gas are usually modern, and oil power stations are usually used in isolated areas (islands for instance) and there is thus limited need for additional investment in most EU countries, with the notable exception of Italy.

implying annual investment of about €72 billion, which is slightly less than the annual average in the past ten years. Around 77 percent of this investment would be needed in the electricity sector, out of which two-thirds for electricity generation. The gas sector (gas production, import facilities, and transport) comes next, accounting for 12.3 percent of the total. Investment in renewable energy sources is projected to amount to almost 23 percent of total investment. Most of this (some 80 percent) is for renewable electricity production.

**Investment in renewable energy sources is projected to amount to almost 23 percent of total investment.**

**Figure 1. Age structure of EU-25 electricity generating capacity**



Source: Güldner (2007).

**Table 2. EU-27 cumulative energy investment needs, 2005-30**

Energy sub-sector	Billions of euros	% of total
Oil (development, exploration, refining)	90	5.1
Gas (exploration, development, distribution)	221	12.3
Coal (mining, shipping)	24	1.3
Renewables (heating, transport)	78	4.4
Electricity	<u>1,377</u>	<u>76.9</u>
Generation	<u>897</u>	<u>50.0</u>
Gas	148	8.3
Oil	19	1.0
Coal	261	14.6
Renewables	327	18.3
Nuclear	141	7.9
Transmission	116	6.5
Distribution	364	20.3
<b>TOTAL</b>	<b>1,790</b>	<b>100.0</b>

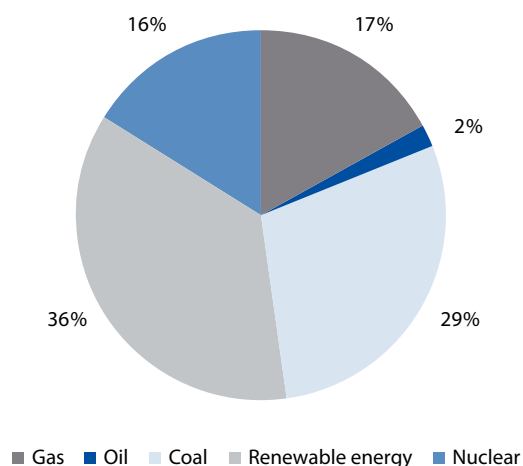
Source: European Commission (2007c)

Notes: This is the Commission's baseline scenario, i.e., not the policy scenario resulting in a 20 percent reduction in GHG emissions, a 20 percent share of renewable energy, and a 20 percent decline in energy consumption targeted to result from energy efficiency measures.

**Electricity sector investments will not only account for the bulk of energy sector investment, but they will also play a key role in achieving EU energy objectives.**

Electricity sector investments will not only account for the bulk of energy sector investment, but will also play a key role in achieving the energy objectives of the EU – as in the past. In the baseline scenario, total investments in electricity are estimated at €900 billion in the period to 2030. As Figure 2 illustrates, renewable energy sources are projected to account for 36 percent of this investment, followed by coal-fired generation (29 percent), gas (17 percent), and nuclear (16 percent).

Figure 2. Sectoral breakdown of EU-27 cumulative electricity sector investments, 2005-30



Source: Commission (2007c)

As discussed above, although informative, the baseline scenario is not in line with the EU objectives agreed on at the European Council of March 2007. To meet these objectives, additional investments in energy efficiency and renewable energies will be needed. Successfully implemented energy efficiency policies will reduce the investment needs in the energy sector, as they will decrease energy demand growth. However, they will require investments in the energy-consuming sectors. These investments are hard to quantify, but they may be similar to the investments avoided in the energy sector. This is because many of the measures to increase energy efficiency called for under the Commission's Action Plan for Energy Efficiency (European Commission 2006e) are capital intensive. Measures concern, in particular, the development of CHP and those aimed at raising energy efficiency in buildings and transport – areas where the Commission identified most of the energy efficiency potential.

The aim for renewable energy is to double – relative to the baseline scenario – its share in total energy consumption by 2020. This implies a significant increase in investments in this field. However, biomass is expected to cover a substantial part of the renewable energy expansion, and using biomass as a fuel in electricity generation might not require substantial investments in the energy sector, as biomass can be used in existing coal and lignite power stations. The investment in renewable energy will also depend on progress in reducing their cost through innovation and scale effects. From the impact assessment study carried out by the Commission (2007b), meeting the 20 percent renewable energy target by 2020 will require investments in renewable energy of the order of €600-670 billion in 2005-20. This is a significant increase in relation to the baseline scenario (2.5 times in yearly investments).

The investment needs in conventional power stations (leaving aside renewable energy) are difficult to forecast. As mentioned above, meeting the EU climate change objective is bound to lead to an accelerated replacement and modernisation of existing power stations. Therefore, it is reasonable to assume that the new capacity to be built in the years to come will increase significantly. However, depending on the technologies chosen, building new capacity will have very different investment implications. There are three possible options: CCGT using gas, coal-fired power stations, and – in some countries – nuclear power stations. These options have very different investment costs: about €600/kW for a CCGT using gas, €1,200/kW for a new coal power station, and around 1,800 €/kW for nuclear power stations.<sup>8</sup> Which option each EU country will favour depends on security of supply considerations and the national GHG emissions target. If coal and gas power stations were to be CCS-equipped, the cost of investing in these two options would dramatically increase. At present, the cost of CCS might double the initial investment outlays in a new plant depending on the technology used, but CCS costs are expected to decrease in coming years.

To conclude, achieving EU energy policy objectives will require a substantial expansion of energy related investments (in the energy sector and in the other sectors). Most of the expansion will take place in the period to 2020. The investment expenditure needed for the expansion depends on a variety of factors. In the long run, cost could decline as a result of R&D efforts and with a greater market penetration of new technologies. This being said, a fast implementation of investments might create bottlenecks in the industries producing energy equipment and in biomass production, which might put upward pressure on prices and thus investment expenditure and other expenditures (e.g. biomass cost). All in all, it seems that the European Union is heading for another cyclical energy investment boom – similar to the ones after the two energy crises in the 1970s. However, the duration of this investment boom may be much longer than earlier ones. Equally important, while the scope of the investment required to achieve EU policy objectives can be estimated, the exact timing and composition cannot – mainly because of uncertainties about the options chosen and specifics of the policy priorities EU and its members intend to pursue to achieve these objectives. The next section sheds more light on this issue.

*There is a risk that fast implementation of investments will create bottlenecks in biomass production and in industries producing energy equipment.*

## **4. Energy investment decisions in an uncertain environment**

### **4.1 Taxonomy of investment risks**

In this section, different factors influencing the investment decision in the energy sector will be analysed, with particular emphasis on policy and regulatory factors. The decision to invest results from an analysis of expected developments in key variables influencing the profitability of the investment under consideration. Changes in policies, regulations, energy prices, technology, and administrative and environmental procedures are traditional risks affecting energy investments. Moreover, risks stem from limited experience with the functioning of newly liberalised electricity and gas markets. Therefore, the investment environment seems particularly challenging at present. Broadly distinguishing between economic, political, and legal risks, Table 3 gives a non-exhaustive list of risks facing energy sector investments.

<sup>8</sup> The investment cost of new nuclear power stations in the EU is very uncertain and will vary depending on the country and the technology. The cost quoted corresponds to the new nuclear power station in Finland, which is presently under construction. However, this power station is experiencing cost overruns (covered by the provider of the equipment, Areva) and delays.

**Table 3. Taxonomy of risks facing energy sector investments**

<b>Economic risk</b>	
Market risk	Inadequate price and/or demand to cover investment and production costs Increase in input cost
Construction risk	Cost overruns Project completion delays
Operation risk	Insufficient reserves Unsatisfactory plant performance Lack of capacity of operating entities Cost of environmental degradation
Macroeconomic risk	Abrupt depreciation or appreciation of exchange rates Changes in inflation and interest rates
<b>Political risk</b>	
Regulatory risk	Changes in price controls and environmental obligations Cumbersome administrative procedures
Transfer-of-profit risk	Foreign exchange convertibility Restrictions on transferring funds
Expropriation and nationalisation risk	Changing title of ownership of the assets
<b>Legal risk</b>	
Documentation or contract risk	Terms and validity of contracts, such as purchase/supply, credit facilities, lending agreements and security/collateral agreements
Jurisdictional risk	Choice of jurisdiction Enforcement risk Lack of a dispute-settlement mechanism
<b>Force majeure risk</b>	
	Natural disaster Civil unrest Strikes

Source: Sullivan and Blythe (2006)

**Governments influence all key variables of the investment decision: from demand expansion to support of certain energy sources and the penalisation of others.**

Governments influence all key variables of the investment decision: from demand expansion (energy efficiency policies) to support of certain energy sources and the penalisation of others by modifying energy prices through taxes and subsidies. The review of the EU energy policies taking place at present creates uncertainties and a wait-and-see attitude of market players.

Energy policies should be formulated with a view to influencing investment decisions and operational behaviour of the companies in the most effective way. Stern (2006, p.325) indicates that the “three essential elements for an effective policy framework are credibility (belief that the policy will endure, and be enforced); flexibility (the ability to change the policy in response to new information and changing circumstances); and predictability (setting out the circumstances and procedures under which the policy will change)”.

If uncertainties are high, as at present, companies may be slow in responding to price signals. Responses would likely be gradual and may not achieve deep structural change needed to reach a more efficient outcome (Blyth and Hamilton 2006). However, if the policy framework provides certainty for a large enough period, investments can be stimulated, as shown – for instance – by the experience with feed-in tariffs in a number of countries (see Finon, this volume).

By comparison to a planning system, now policy makers need to become more precise about their policies and adapt policy instruments to changing circumstances, in order to avoid raising the cost of capital by creating policy and regulatory uncertainty.

In liberalised energy markets, market-based instruments – such as the EU Emissions Trading Scheme (ETS) – have greater potential than non-market based instruments to achieve the objectives in an efficient way. However, market participants might react too slowly to price signals for different reasons. As a result, a combination of market and non-market instruments will be used. Governments will adapt the instruments depending on the results.

In the following sub-section, traditional price risks will be briefly analysed. Other traditional risks are related to possible delays and cost overruns due to administrative and environmental procedures and public opposition. Additionally, in an environment of fast technological progress in the years to come, the risk will rise that equipment will become obsolete much faster than anticipated.

#### **4.2 Traditional price risks**

Energy companies face a range of risks and uncertainties when making an investment decision. In competitive markets energy price risk is a traditional risk.

*In competitive markets, energy price risk is a traditional risk.*

It is normal practice to define scenarios for long-term energy prices. These scenarios reflect the ‘vision’ of institutions and market players of long-term developments. The substantial rise of oil prices since end-2003, which initially was seen as a short-term phenomenon, was gradually perceived as a sign of the end of the period of low oil prices that had been prevailing since the mid-1980s. Higher energy prices now projected on the basis of this reassessment reflect a more pessimistic view on oil resources and the price elasticity of oil demand. The new energy scenarios considered at present (IEA 2006 and European Commission 2006c) not only show higher energy prices, but also a substantial change in relative energy prices. European gas prices are assumed to remain linked to oil prices. The ratio between coal prices, on the one hand, and oil and gas prices on the other hand has decreased substantially and thus coal competitiveness has improved under the current scenarios.

The upward revision of oil and gas price scenarios implies that, other things remaining equal, the profitability of investments in oil and gas production, energy savings (except for coal), renewable energy sources, nuclear energy, and equipment to use coal (such as power stations and boilers) has increased. By contrast, the profitability of investments related to the use of oil and gas has decreased, notably for power stations using these fuels. Investment in the transmission and distribution of electricity, gas and oil should be largely unaffected. However, the profitability of such investment might be affected indirectly, as higher energy prices might lower the use of transmission and transport infrastructures – gas and oil pipelines, for instance – thereby depressing transmission and transport prices. The profitability of refinery investments is also not directly affected by the level of oil prices, but by price differentials between different types of crude oil and petroleum products (heavy vs. light crude and low-sulphur vs. high-sulphur fuel, for instance). These changes in the profitability of energy investments have already influenced investment trends in recent years, as shown – in particular – by the rapid expansion of coal in power generation.

There is considerable debate on the possibility to forecast long-term energy prices. Stirling (1994) argues that for most energy investment decisions, it is not possible to assign probabilities to alternative future developments. Other analysts – Awerbuch and Berger (2003), for instance – consider that historical variability provides a good guide for the future. Nonetheless, they add: “This is not to say, however, that certain fundamental changes in the future, such as significant market restructuring or radical new technologies, could not create ‘surprises’ by altering historical patterns” (Awerbuch and Berger 2003, p.17). This has indeed happened in the oil market, which has gone through several phases, characterised by different energy price levels.

In any case, there is considerable uncertainty about future energy price developments and oil price volatility has increased since the oil price drop in early 1986 (Regnier 2007). Therefore, the best way to mitigate energy price risks seems to be to diversify the portfolio of energy assets. Generally, energy companies diversify their portfolios to cover against different risks (political, energy prices, and others). Assets poorly diversified (concentrated on a single source) will benefit the most from diversification –and *vice versa*. The portfolio theory has been applied to electricity systems in order to analyse the portfolio benefits of different diversification strategies to protect against energy price risks. This approach, pioneered by Awerbuch, is presented in detail in Awerbuch and Yang (this volume).

#### **4.3 Risks due to unclear climate change policies**

Concern about climate change, particularly deep cuts of GHG emissions, is a relatively new feature of the energy policies in Europe, gaining prominence just after the turn of the century. Compared to other environmental impacts, it so far lacks policy credibility. As Stern (2006, p.25) pointed out, climate change is “the market failure on the greatest scale the world has seen”.

**To substantially reduce policy uncertainty, policy makers need to clearly communicate on the post-2012 approach addressing climate change ...**

To eliminate – or substantially reduce – policy uncertainty, policy makers need to clearly communicate on the post-2012 ambition and approach. This uncertainty is a barrier to investment and leads companies to choose investment strategies that are sub-optimal from society’s viewpoint as they fail to achieve climate change objectives (see Sullivan and Blyth 2006, for instance).

There is no doubt that after 2012 a system to reduce emissions will continue, but there is uncertainty about emissions targets and the instruments to enforce the regulatory mechanism. In part, this is related to the international commitments on GHG emission reductions. In essence, EU policy makers might consider a strong policy to combat climate change that is not accompanied by sufficient international support detrimental to the international competitiveness of EU economies. If this policy is left to national governments alone, they have incentives to review objectives *ex post* if costs become high in a certain period. The EU institutions can thus provide a certain degree of independence in policy implementation by monitoring and enforcing objectives and instruments set at EU level.

Policy makers might not accept targets that lead to high CO<sub>2</sub> prices. On the other hand, only relatively high CO<sub>2</sub> prices that prevail long enough will promote the development of new low-carbon technologies. This, in turn, will stimulate cost reductions in low-carbon technologies. This virtuous cycle will lower CO<sub>2</sub> prices in the long run.

Efforts to develop a clear and predictable long-term climate change policy are further complicated by a possible conflict between climate change objectives and security of supply objectives. This is notably the case for coal. The natural reaction of markets to higher oil and gas prices is to diversify away from such fuels. Coal appears to be the easiest way to achieve this diversification.



However, an increasing use of coal raises CO<sub>2</sub> emissions – at least in the short- and medium term. The conflict between the use of coal and climate change objectives will disappear only in the long run as and when CCS technologies have reached commercial maturity. But it is also true that a credible long-term climate change policy spurs the development of clean coal technologies, notably CCS. As a result, while there is a conflict between security of supply and climate change objectives over the medium term, this conflict eventually subsides – or even disappears in the long run. One can turn this argument around: uncertain climate change policies today delay investments that would strengthen security of supply tomorrow.

*... which would also be good for security of supply reasons, as uncertain climate change policies today delay investments that would strengthen security of supply tomorrow.*

It is worth noting that there is a complex relationship between the energy price risk discussed in the previous sub-section and the CO<sub>2</sub> price risk discussed here (IFRI 2006). This relationship depends on the emission target, energy prices, economic growth, and the development of low-carbon technologies. To illustrate, everything else being equal, an increase in gas prices makes coal more competitive in power generation and thus increases CO<sub>2</sub> emissions. As a result, for a given CO<sub>2</sub> emission target, the CO<sub>2</sub> price rises. The investment implication of all this depends on whether or not the investment is covered by the EU ETS.

For investments covered by the EU ETS, the CO<sub>2</sub> price will be influenced by changes in energy prices. To some extent, this limits the risks of the investments that contribute to achieving the GHG emission target. However, for the sectors outside the EU ETS, the viability of the investments contributing to reduce GHG emissions is substantially exposed to energy price volatility risks. Everything else being equal, the profitability of these investments (in energy efficiency, for instance) drops with a decline in fossil fuel prices. To ensure an acceptable profitability of investments outside the EU ETS, governments should put in place a mechanism to make up for this impact, for instance, using taxes or subsidies to compensate for changes in energy prices.

#### **4.4 The case of investments in power generation**

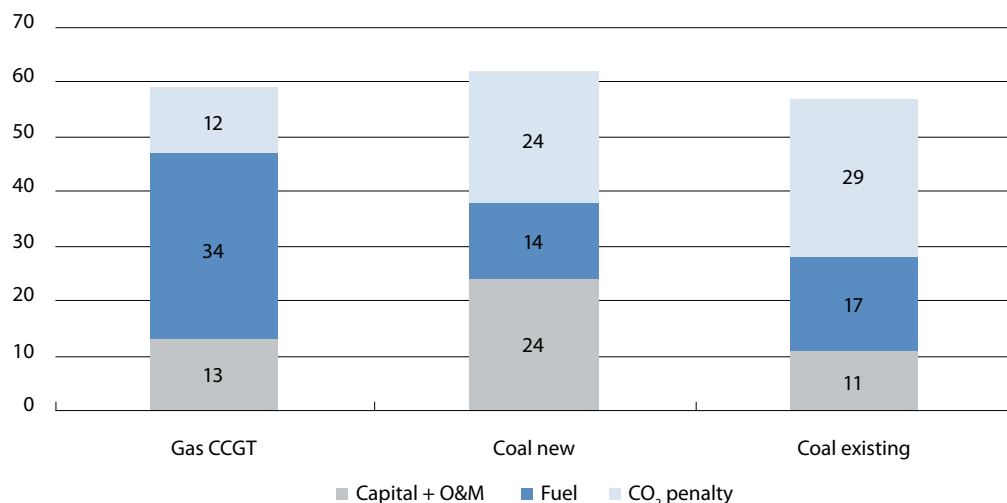
In this sub-section, we will briefly analyse the case of investments in power generation in the EU. As argued above, the power sector will play a key role in implementing EU policy objectives and it is projected to account for the bulk of total energy investments. In principle, this analysis requires a country-by-country (or group of countries) approach because the EU electricity market is not yet well integrated due to limited interconnection capacity. However, to illustrate the impact of uncertainty on investment decisions, it is pertinent to look at a 'typical' EU country, which we do in what follows.

Leaving aside nuclear, which is a realistic option in only a few countries and depends in any event on political decision, electricity companies can generally choose between three possible options to invest in new generation capacity: renewable electricity, CCGT using gas, and coal-fired power stations. As for renewable electricity, member states will establish national renewable energy targets to contribute to meeting the EU renewable energy target. Therefore, renewable energy capacity expansion will be largely determined by policy decisions (financial support schemes). For the rest of the electricity capacity needs, the choice is between gas-fired CCGT and coal power plants. Another option in the medium term is to delay as much as possible the decommissioning of existing plants. This concerns mainly coal power stations, as they will be the first to reach the end of their life.

Figure 3 presents the costs of electricity for the gas and the coal options, based on average EU investment and operating and maintenance (O&M) costs and on the EU energy price scenarios. Under these scenarios, the cost of electricity in a new, modern coal power station is significantly lower (over 20 percent) than in a new CCGT using gas; this is for a real discount rate of 5 percent.

In practice, a more refined comparison accounts for the cost of access to gas and coal, which vary depending on the country and location of the power station.

**Figure 3. Electricity production cost (in €/MWh)**



Source: Own calculations

Notes: Estimates for a typical location in the EU; 5 percent real discount rate; €30/t CO<sub>2</sub>; \$55/t coal; gas baseline price scenario IEA (2006).

Introducing a CO<sub>2</sub> price in the calculation significantly affects this comparison. Both alternatives have similar costs for a CO<sub>2</sub> price of around 25 €/t CO<sub>2</sub>. Coal is cheaper than the gas option for CO<sub>2</sub> prices below €25/t CO<sub>2</sub> and *vice versa*.

The cost of electricity in an existing coal power station is normally substantially lower than in a new one, considering as sunk the existing investment in the plant. However, introducing a CO<sub>2</sub> price affects existing coal power stations more than new ones because the former are less energy efficient than the latter (typically, the efficiency of existing plants is more than 20 percent below new ones). Existing coal-fired power stations would cease to be competitive with new ones at a CO<sub>2</sub> price of around €50/t CO<sub>2</sub>. But as argued above, at that price, gas-fired CCGT plants would clearly be the most economic choice. It should also be pointed out that there are substantial variations in terms of cost and energy efficiency of the existing plants. Therefore, the CO<sub>2</sub> price range that makes the generating cost of an existing coal power station equal to the cost of a new one is wide and for the less efficient plant can be less than €20/t CO<sub>2</sub>.

**Because of low CO<sub>2</sub> prices, there are currently no incentives to replace existing coal power stations with new, more efficient ones.**

The objective of the EU to achieve at least a 20 percent reduction in CO<sub>2</sub> emissions by 2020 will put a substantial constraint on the GHG emissions from the power sector. Indeed, the Commission's scenarios suggest that meeting the CO<sub>2</sub> emissions target would result in a substantial decrease of the use of coal in power generation. This implies that the CO<sub>2</sub> price would have to increase to levels ensuring that inefficient existing coal power stations are decommissioned or modernised. It is difficult to estimate the level of CO<sub>2</sub> prices compatible with this objective, but under our cost estimates it may be around €30/t CO<sub>2</sub>. At present, the CO<sub>2</sub> price in the EU ETS system is much lower than this figure and there are substantial uncertainties on its future development. Therefore, there are currently no incentives to replace existing coal power stations by more efficient ones. But even if these incentives were sufficiently strong: should existing coal power stations be replaced by new coal power plants or by gas-fired plants?

This is difficult to say. If the renewable and energy efficiency objectives are achieved (20 percent in both cases by 2020) the current CO<sub>2</sub> reduction target for 2020 (-20 percent) could be easily achieved and thus the CO<sub>2</sub> price may remain at moderate levels, everything else remaining equal. This will favour the coal power plant option, at least in the period up to 2020. By contrast, if the renewable energy/energy efficiency targets are not achieved and the expectations are to keep a relatively tight emission target, the CO<sub>2</sub> price would tend to become much higher than at present. In this case, the gas-fired plant option would be favoured. However, a new power station commissioned in 2010-15 will still be in operation up to 2040 at least. Therefore, it is necessary to analyse long-term scenarios.

In the long run, it is very likely that coal power stations will need to be equipped with CCS, if the objective of substantially reducing CO<sub>2</sub> emissions is pursued (the objective is to cut CO<sub>2</sub> by 60-80 percent by 2050 in industrialised countries). However, CCS technologies are expected to be commercially available by 2020. At present, CCS costs (including transport and storage) around €35-€65/t CO<sub>2</sub> (own estimates based on different sources). Looking beyond that time horizon, CCS cost could possibly decline to €25-€35/t CO<sub>2</sub> for suitable locations (own estimates based on different sources). However, this is far from certain, as for any new technological development. It follows that investments in coal-fired electricity generation face the considerable long-term risk that CCS cost turn out to be much higher than currently expected. Gas-fired plants are significantly less exposed to the risk related to CCS technologies, as they emit substantially less CO<sub>2</sub> than coal-fired plants.

In addition, the result of the comparison between the gas and coal options is very sensitive to the energy price assumptions. An increase in energy prices by 20 percent increases the electricity costs (without environmental externality costs) of the gas option by 15 percent, while the increase is less than 8 percent in the case of a new coal-fired power station.

All in all, the dilemma for electricity companies is that a new modern coal power station is exposed to substantial CO<sub>2</sub> price risk and related CCS risks. By contrast, a gas-fired plant is substantially less exposed to the CO<sub>2</sub> price risk, but it is exposed to the gas price risk.

Confronted with all these risks and policy uncertainties, electricity companies will tend to limit investments. There is also a risk that they develop investment programmes that are not compatible with the objectives of the EU energy policy. Electricity companies will have to diversify their portfolio of power stations particularly towards portfolios that limit their exposure to CO<sub>2</sub> and energy price risks.

## 5. Conclusions

The oil price increase since 2003 has triggered a revision of energy policies in the EU with a view to reducing energy import dependency and GHG emissions. Previous policies – adopted in the 1980s – focussed on the liberalisation and privatisation of energy markets, with limited scope for government intervention in energy matters. These policies do not seem to be able to address climate change and security of supply challenges. New forms of government intervention and more intervention will be needed to change energy trends. In order to achieve the energy policy objectives, governments should create strong and credible incentives to influence market players. Currently, there is considerable policy uncertainty, with policy makers debating the objectives and the adequate policy instruments to address them. The key objectives of the EU policy cannot be achieved in an effective way without a coordinated approach at EU level. This is a historical opportunity for the EU institutions to play an important role in the energy policy.

***Possible investment in new coal-fired electricity generation faces the risk that the cost of carbon storage and capture turn out to be much higher than currently expected.***

***Increasing energy efficiency and expanding renewable energy are crucial for achieving EU energy policy objectives.***

Increasing energy efficiency and expanding renewable energy are crucial for achieving EU energy policy objectives. In the long run, the use of coal and gas will only be compatible with the climate change objectives if CCS technologies are available at a reasonable cost, but CCS technologies are still in the demonstration phase. EU policies will support fast technological progress and penetration of low-carbon technologies. The future role of nuclear power is uncertain at this stage.

Energy investments in the EU have remained at relatively low levels during the last two decades, as a result of overcapacities created after the two energy crises in the 1970s and a gradual reduction of the energy demand growth. Most of the energy investment went to the power sector, around 80 percent of the total. In the European Commission's baseline energy scenario up to 2030, energy investments would remain at the current level. However, this baseline scenario would lead to an increase in CO<sub>2</sub> emissions and import dependency. The aim of the EU policy is to prevent this increase. The energy objectives of the EU are very ambitious, particularly the objective of reducing CO<sub>2</sub> emissions by at least 20 percent by 2020 and further reductions later. This will require a substantial increase in energy investments, mostly in the power sector, particularly in renewable electricity generation. At the same time, there is likely to be an accelerated replacement of the old inefficient power stations by modern ones. The period 2010-20 is critical, as many long-life investments will be decided then.

Market players need clarity on policy objectives and on the instruments to achieve them. Policy and regulatory uncertainty increase the risk premium companies have to account for when considering investments. In a context of highly volatile energy markets and a fundamental review of energy policies, the degree of uncertainty affecting investment decisions has increased. More importantly, with the pricing of CO<sub>2</sub>, another significant uncertainty has been added to traditional energy investment risks.

Climate change policies are relatively new and it takes time to establish credibility. These policies will have a substantial impact on energy investment decisions. The uncertainty related to the development of the EU ETS post 2012, and climate change policies in general, limits investments in low-carbon solutions and energy investments in general. This is because major energy investments need a predictable long-term framework so that investors can properly assess risks and returns.

All these uncertainties prevent the realisation of the investment needed to achieve EU policy objectives. However, once a clear policy framework is put in place, energy companies will launch substantial investment programmes. This may lead to tensions in the sectors supplying energy equipment and services, particularly low-carbon technologies. Some companies that adopt a strategic behaviour by taking risks in advance of concrete policy developments may benefit from the situation. More importantly, confronted with high uncertainty, companies will tend to better diversify their portfolio of assets in order to manage risks, notably CO<sub>2</sub> and energy price risks.

Finally, a brief analysis of current investment challenges in the EU electricity sector was carried out. At present, electricity companies face the following dilemma: on the one hand, they currently have limited incentives to rapidly reduce CO<sub>2</sub> emissions; on the other hand, before too long, they will have to substantially reduce CO<sub>2</sub> emissions if the policy necessary to achieve EU CO<sub>2</sub> targets is implemented. In these circumstances, companies are reluctant to invest and there is a high risk that the investment they do carry out is incompatible with the EU's ambitious CO<sub>2</sub> reduction targets.

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